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DESIGN & ANALYSIS OF SOLID & HOLLOW IMPELLERS FOR AERO ENGINE APPLICATION

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ABSTRACT

This paper represents Design & Analysis Of Solid & Hollow Impellers For Aero Engine Application In the present work, an analysis is carried out to check the solid and hallow impellers for their performance under rotational, interference and blade connection. Initially Profile representation of impeller segment and imported to ANSYS in SAT file format. The solid elements are used for meshing the object. The shaft hub interference region is constrained and applied the structure. The results are captured for radial, hoop and von mises stresses. Then a cylindrical cutout is made near the small end of impeller and stress analysis is carried out. Again a cylindrical cutout is made near the big end of impeller and stress analysis is carried out to check the performance of the impellers. This can be attributed to the nearness of cutout region near the big end where more mass is concentrated. Also modal Analysis can be used to analyze the behavior. Further analysis is carried out with interference of 25 microns at the inner region of impeller segment. This interference automatically reduces the stresses generated in the structure due to induced compressive stresses on the outer region.

KEYWORDS: Impeller Profile, Hollow Impeller, Methodology, No .of Cut Outs

Original Article

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INTRODUCTION

Impeller is important component of Aero Engines. Since weight is very important in aero engines, the project is carried out to study the effect of hollow impellers on the stress and structural stability. Through the use of FEA, the impeller design can be optimized to minimize weight while maximizing strength and stiffness. This enable cost reductions through reduced material and fabricating costs while enabling natural frequencies to be avoided and extended impeller life. In hollow impeller the cylindrical cutout is built to reduce the weight of the structure. Since mass is very important in generating the stresses as well as weight, any reduction in weight with higher capacity increases the payload capacity of aero-planes. The mounting of blades and number blades also influence the stress generation in the problem. Filleting of main blades with disc part also plays a role in stress and stiffness in the structure. Modal analysis is the process of determining all the modal parameters, which are then sufficient for formulating a mathematical dynamic model. Determine modal parameter of a mechanical structure by analytical methods. Results of this investigation are expected to correlate closely with Experimental results. Modal analysis is carried out to check the rigidity of hollow and solid impellers.

OBJECTIVES

The main objective of analysis is carried out to check the solid and hallow impellers for their performance under rotational, interference and blade connection. An analysis is carried out filleted and without filleted blade region with impeller.

Hollow Impeller

The cylindrical cutout is built to reduce the weight of the structure. Since mass is very important in generating the stresses as well as weight, any reduction in weight with higher

Capacity increases the payload capacity of aero-planes. The finite element model is built using 8 noded solid 45 elements.

Impeller Fillet

Impellers in real applications are mounted with main blades and splinter blades for flow passage. The mounting of blades and number blades also influence the stress generation in the problem. Filleting of main blades with disc part also plays a role in stress and stiffness in the structure. So to study the effect of fillet on stress distribution, blade and splinter blades are mounted on cyclic symmetry model of 32.727 0(11main blades for 3600) of main disc.

METHODOLOGY

Impeller is important component of Aero Engines. Since weight is very important in aero engines, the project is carried out to study the effect of hollow impellers on the stress and structural stability. Initially the solid geometry is imported from Pro E in 'sat' file format and imported to ANSYS. The object is revolved to form three dimensional bodies. The object is meshed with 8 noded Solid45 elements. A rotational load of 4650 rad/sec is applied fixing the center hub-shaft interface. The results are obtained for deformation, Von Mises, radial, and hoop stresses. Similarly hollow cylindrical cutouts are made in the geometry and meshed. The meshed geometries are analyzed with the same loading conditions. Similarly modal analysis is carried out to find the effect on natural frequency of the system.

METHODS OF DESIGN & ANALYSIS

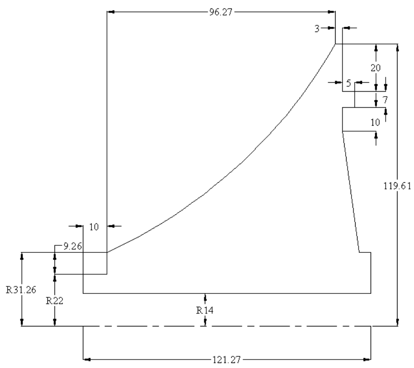

Figure 1: Geometrical Representation of the Solid Impeller

This is the design and analysis of solid and hollow impeller model with the material properties of Titanium. First basic three dimensional model of the impeller is created. Then impeller segment is imported to ANSYS in SAT file format. Applying Material properties on the model feature. The solid elements are used for meshing the object. The shaft hub

interference region is constrained and a rotation load is applied on the structure. The results are captured for Structural Analysis. Then a cylindrical cutout is made near the small end of impeller and stress analysis is carried out. Again a cylindrical cutout is made near the big end of impeller and stress analysis is carried out to check the performance of the impellers. This can be attributed to the nearness of cutout region near the big end where more mass is concentrated. Also modal Analysis can be used to analyze the behavior. Further analysis is carried out with interference of 25 microns at the inner region of impeller segment. This interference automatically reduces the stresses generated in the structure due to induced compressive stresses on the outer region. The analysis is carried out with unfiltered and filleted blade region with impeller. All the results are presented with necessary graphical plots.

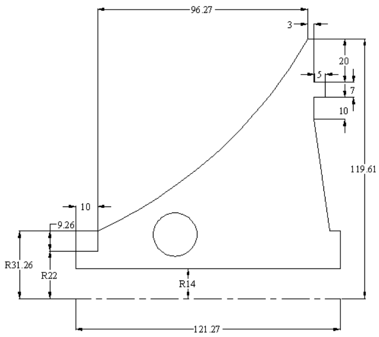

Figure 2: Geometrical Representation of the Hollow Impeller

First stapes of the design of impeller is geometrical representation of the impeller. The profile of the impeller is shown in a figure. These geometrical profiles draw in a Pro-E and then convert it in to three dimensional Models. The geometric representation of impeller having outer radius of 119.5 mm, inner radius of 14 mm and 122 mm axial length. Figure shows the model of the Impeller.

Stress Analysis

During the design process of this impeller, investigations were carried out in order to determine stresses and deformations, which led to the identification of possible optimization regions. The geometries were analyzed under mechanical loads, among which the best ones were selected for further analysis including application of aerodynamic (fluid) loads as well. Geometrical model stress analyses for radial stress, hoop stress & von mises stress with single & double cut out.

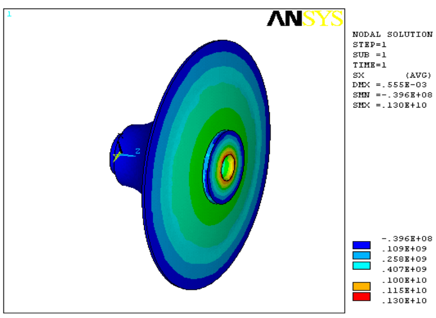

Figure 3a: Radial Stress in the Impeller

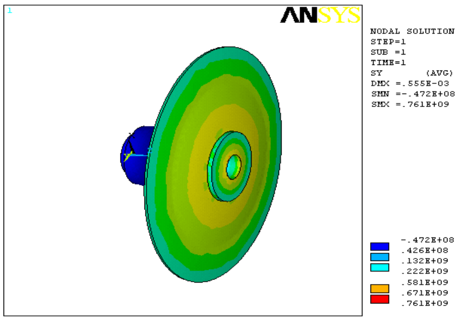

Figure 3b: Hoop Stress Plot of the Impeller

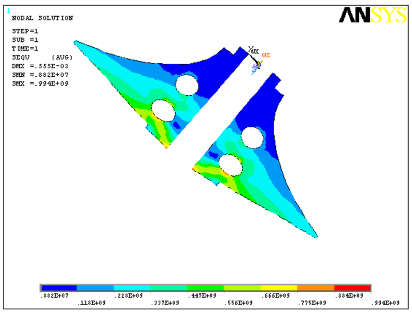

Figure 3c: Von Mises Stress across the Cutout Region of the Impeller

Modal Analysis

Modal analysis is the process of determining all the modal parameters, which are then sufficient for formulating a mathematical dynamic model. Modal analysis may be accomplished either through analytical or experimental technique. Most practical noise and vibration problems are related to resonance phenomena, where the operational forces Excite one or more of the modes of vibration. Modes of vibration that lie within the frequency range of the operational dynamic forces always represent potential problems. An important property of modes is that any forced or free dynamic response of a structure can be reduced to a discrete set of modes. The modal parameters of all the modes, within the frequency range of interest, constitute a complete dynamic description of the structure. Hence the modes of vibration represent the inherent dynamic properties of a free structure (a structure on which there are no forces acting). Geometrical model modal analyses for with single & double cut out.

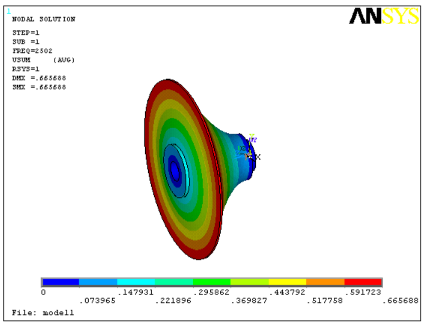

Figure 4a: Modal analysis Results for Solid Impeller

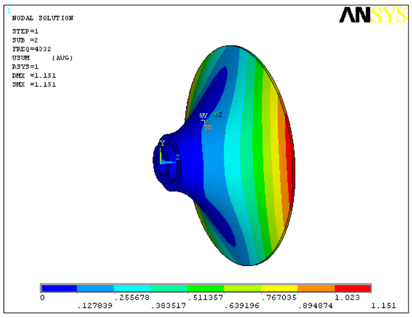

Figure 4b: Modal Analysis Results -One Cylindrical Cutout

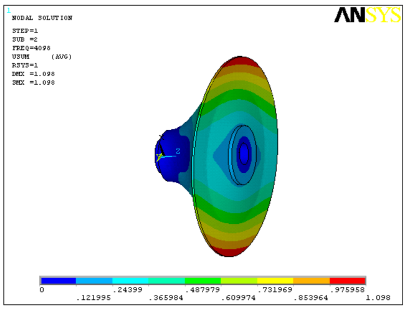

Figure 4c: Modal Analysis Results-Two cylindrical cutouts

RESULTS & DISCUSSIONS

Stress Analysis Comparison

Table 1: Stress Comparison between Impeller with Fillet Blade Regions and without Fillets

Description	Deformation (mm)	Radial Stress (MPa)	Hoop Stress (MPa)	Von Mises Stress (MPa)
Impeller without fillet	1.705	560	540	669
Impeller with fillet	1.45	524.7	817	694

Table 1 shows the comparison between impeller with fillet blade regions and without fillets. The result shows higher stiffness for impeller with fillet region by comparing the deformation in the structure. Radial stress in impeller with fillet is reducing and where as hoop stress is increasing. This can be attributed to thin strip of weld which contains less resisting area at the joint in circumferential direction joining on the disc surface. Also due to addition of fillet material, Von Mises stress is marginally increased due to higher inertia effects which combines with the effect of mass(mass*acceleration).

Modal Analysis Comparison

Table 2: Modal Analysis Comparison between Solid and Hollow

Description	First Natural Frequency (Hz)	Second Natural Frequency (Hz)
Solid Impeller	2502	4500
Single cutout	2348	4332
Double cutout	2256	4098

Impeller

Table 2 shows the modal analysis comparison between the solid and hollow impellers. Modal analysis comparison shows reduction in the natural frequency values with single cylindrical cutouts representing lower natural frequencies prone to more vibration. There is a drop of 6% natural frequency can be observed. With two cutouts 10% drop of natural frequency can be observed. This can be attributed to reduced stiffness of the structure.

CONCLUSIONS

The results are captured for radial, hoop and Von Mises. By comparing the results almost 3% stress raise can be observed with single cylindrical cutout. Two cylindrical cutouts are created, Almost 58% increase of stress can be observed compared to the solid impeller. Interference load reduces the stresses generated due to rotational loads due to initial compressive load on the structure. This analysis is carried out without filleted blade region the results shows 6% drop of natural frequency with the hollow impeller system and 10% drop with two cutouts.

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